CAVH: Filtration On ECMO
Adults (and paeds).

Clarke Thuys CCP FANZCP

Disclosure
• Nothing to disclose.

Where it all began

How Many Adult ECMOs need RRT?
### How Many Adult ECMOs need RRT?

<table>
<thead>
<tr>
<th>Study</th>
<th>Number of Patients</th>
<th>Number / % dependent on RRT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brogan et al. (2009)</td>
<td>1473</td>
<td>648 / 44%</td>
</tr>
<tr>
<td>Yan et al. (2010)</td>
<td>67</td>
<td>36 / 44.8%</td>
</tr>
<tr>
<td>Wu et al. (2010)</td>
<td>68</td>
<td>187 / 44%</td>
</tr>
<tr>
<td>Lee et al. (2010)</td>
<td>68</td>
<td>185 / 49.4%</td>
</tr>
<tr>
<td>Chen et al. (2011)</td>
<td>102</td>
<td>26 / 25%</td>
</tr>
<tr>
<td>Lee et al. (2012)</td>
<td>181</td>
<td>76 / 42%</td>
</tr>
<tr>
<td>Kohler et al. (2011)</td>
<td>201</td>
<td>56 / 27.8%</td>
</tr>
<tr>
<td>Aubois et al. (2012)</td>
<td>158</td>
<td>98 / 62.7%</td>
</tr>
<tr>
<td>Schmitt et al. (2014)</td>
<td>105</td>
<td>100 / 100%</td>
</tr>
<tr>
<td>Artigas et al. (2014)</td>
<td>135</td>
<td>62 / 46.7%</td>
</tr>
<tr>
<td>Nicol et al. (2014)</td>
<td>421</td>
<td>179 / 42.4%</td>
</tr>
<tr>
<td>Kim et al. (2014)</td>
<td>732</td>
<td>238 / 32.4%</td>
</tr>
<tr>
<td>Yasuda et al. (2018)</td>
<td>214</td>
<td>86 / 40.1%</td>
</tr>
</tbody>
</table>

### How Many Pediatric ECMOs need RRT?

<table>
<thead>
<tr>
<th>Study</th>
<th>Number of Patients</th>
<th>Number / % dependent on RRT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Askenazi et al. (2011 review)</td>
<td>7941</td>
<td>1761 / 22.5%</td>
</tr>
<tr>
<td>Selewski et al. (2012)</td>
<td>203</td>
<td>57 / 28%</td>
</tr>
<tr>
<td>Hoover et al. (2008)</td>
<td>86</td>
<td>26 / 30.2%</td>
</tr>
<tr>
<td>KIDMO (2016)</td>
<td>83</td>
<td>46 / 55.7%</td>
</tr>
<tr>
<td>Lou et al. (2014)</td>
<td>207</td>
<td>207 / 100%</td>
</tr>
<tr>
<td>Keiser et al. (2015)</td>
<td>154</td>
<td>38 / 20.2%</td>
</tr>
<tr>
<td>Paden et al. (2011)</td>
<td>278</td>
<td>156 / 56.5%</td>
</tr>
<tr>
<td>Santiago et al. (2008)</td>
<td>23</td>
<td>19 / 82.6%</td>
</tr>
<tr>
<td>Weidenrauch et al. (2017)</td>
<td>35</td>
<td>35 / 100%</td>
</tr>
<tr>
<td>Beno et al. (2014)</td>
<td>100</td>
<td>20 / 20%</td>
</tr>
<tr>
<td>Gupta et al. (2014)</td>
<td>3502</td>
<td>3502 / 100%</td>
</tr>
<tr>
<td>Wolf et al. (2010)</td>
<td>154</td>
<td>59 / 38%</td>
</tr>
<tr>
<td>Soni et al. (2006)</td>
<td>46</td>
<td>20 / 52.2%</td>
</tr>
</tbody>
</table>

### Indications for filtration

- **Acute renal insufficiency/AKI**

- **Fluid overload**

- **Biochemical imbalance**

- **Fluid restrictions limiting medical care**

**Acute renal insufficiency / AKI**

- **Acute renal insufficiency** - Oliguria unresponsive to diuretics and serum creatinine > 3 times normal.

- **AKI** – some definitions are not based exclusively on the serum creatinine and may include urine output.

- **ESLO** - The definition of “renal complication” or AKI used by the registry includes the need for renal support therapy (RST) or a threshold serum creatinine (Scr) > 1.5 mg/dL.
**Fluid overload**

“Fluid or volume overload with ECMO is very common.”


“Fluid overload is common.”


**Fluid overload**

“Frequently, large-volume fluid resuscitation is needed to ensure sufficient extracorporeal blood flow in patients initiating ECMO.”

Permissive fluid volume in adult patients undergoing extracorporeal membrane oxygenation treatment. Kim H; Paek JH; Song H; Lee H; Jhee JH; Park S; Yun HJ; Kee YK; Han SH; Yoo TH; Kang SW; Kim S; Park JT. 2018 Critical Care. 22(1):279

• Mortality risk began to increase significantly when cumulative fluid balance (CFB) was 82.3 ml/kg in the cardiovascular disease group.

• In patients with respiratory diseases, the mortality risk increase was significant for those with CFB levels above 189.6 ml/kg.

**Biochemical Imbalance**

Other than those associated with renal insufficiency.

• Acid – Base
• Electrolyte
• Liver dysfunction
• Others

**Fluid Restriction Limiting Medical Care**

• Limited space to allow provision of parenteral nutrition or other solutions in oliguric patients.

• CRRT allows volume removal and permits quasi unrestricted feeding.
Main Modalities of CRRT/Filtration with ECMO

• 2. Connecting a Filter Into the Circuit.
• 3. Combining Two Independent Extracorporeal Circuits
Connecting a Filter Into the Circuit.

FIG. 4. (a) Connecting a continuous renal replacement therapy (CRRT) machine to the extracorporeal membrane oxygenation (ECMO) circuit with a roller pump. The inlet of the CRRT is connected to the venous line of the ECMO before the pump and outlet of the CRRT to the venous line of the ECMO circuit before the bladder or directly to the bladder.

Combining Two Independent Extracorporeal Circuits

FIG. 4. (b) Connecting the CRRT machine to the ECMO circuit with a centrifugal pump. Inlet of the CRRT is connected to the high pressure part of the ECMO circuit post centrifugal pump and outlet of the CRRT circuit to the venous line of ECMO before the pump.

Using additional pressure control lines when connecting a continuous renal replacement therapy device to an extracorporeal membrane oxygenation circuit.

Complications

- Gaseous Emboli
- Fluid imbalance
- Biochemical imbalance
- Clotting/Anticoagulation

These findings suggest that adding CRRT at position “C” is unsafe and not advised for clinical use when using a roller pump. The centrifugal pump circuit showed significantly more microemboli for most configurations when a bladder was not used.
Gaseous Emboli

Fluid Imbalance
- Use the correct form of filtration.
- Know what your goal is.
- Is the goal compatible with the ECMO circuit?
- Rate of fluid removal?
- What exactly am I removing?
- Do I need to replace it?

Biochemical Imbalance
- Know what your goal is.
- Use the correct form of filtration.
- What am I removing?
- What is in the dialysate?
- What is in the replacement fluid?
- How do I keep track of this?
- How often do I need to check?

Anticoagulation for the Filter/CRRT
- Azar 2018 - ECMO heparin
- Chadia 2017 - no data
- Heiss 1987 - ECMO heparin
- Hoover 2008 - No data
- Meyer 2001 - No data
- Paden 2011 - No data
- Quinhua 2017 - No data
- Rubin 2010 - No data
- Santiago 2009 - ECMO Heparin + 5u/kg/hr for CRRT
- Schmidt 2014 - ECMO (APTT 50-70s)
- Symons 2013 - ECMO heparin
- Tijssen 2017 - No data
- Tsai 2011 - No data
- Yetimakan 2017 - ECMO heparin
Anticoagulation for the CRRT? Heparin

• Despite their small sizes, neither unfractionated nor low molecular weight heparins cross the haemofilter membrane into the ultrafiltrate in any measurable quantity. Both heparins were present in plasma at a level suitable for therapeutic anticoagulation.

• Heparin clearance during continuous veno-venous haemofiltration.

Singer M, McNally T, Scrutton G, Mackie I, Machin S, Cohen SL.

Anticoagulation for the Filter/CRRT

Anticoagulation for the CRRT?  Bivalirudin

The direct thrombin inhibitors (DTIs) lepirudin and argatroban have been used to maintain haemofilter patency, in small studies.

Bivalirudin may have pharmacokinetic advantages over other DTIs when used in patients with hepatic and renal impairment.

Bivalirudin provided a safe alternative to heparin therapy and was effective in maintaining haemofilter patency during CVVH.

CONCLUSIONS: Prefilter bivalirudin may be an option to prevent filter occlusion in patients requiring continuous renal replacement therapy. Future studies are needed to validate the safety and efficacy of bivalirudin as a prefilter anticoagulant.

• Prefilter bivalirudin for preventing haemofilter occlusion in continuous renal replacement therapy. Mueller SW; MacLaren R; Fish DN; Kiser TH. Annals of Pharmacotherapy. 43(7):1360-5, 2009 Jul.
Conclusion:

- The type of ECMO pump should influence the position of the CRRT device. With a centrifugal pump, the device should be connected after the ECMO pump because of the risk of air entrapment due to the negative pressure generated by centrifugal pumps, and returning emboli into the pumphead.
- Regardless of the type of pump, the return blood from the CRRT device should be returned prior to the oxygenator to reduce the risk of air or clot being sent to the patient.
- Monitor and maintain desired electrolyte and volume levels.
- Anticoagulation is generally not an issue as standard ECMO anticoagulation protocols should suffice.
Going Out on a Limb

WILLIAM J DEBOIS, CCP, MBA
WOODROW FARRINGTON, M.D.
ARASH SALEMI, M.D.
NEW YORK PRESBYTERIAN HOSPITAL-WEILL CORNELL

Cannulation Techniques for ECMO

- Central Cannulation
- Axillary Cannulation
- Femoral Cannulation
  - Cut-down
  - Percutaneous

Femoral Cannulation Anatomy

Common Iliac Artery and Vein
External Iliac Artery and Vein
Femoral Artery and Vein
Superficial Femoral Artery
Femoral Sheath

Skin crease
Common femoral artery
Femoral artery
Suprascapular artery
Saphenous vein
Difficulties in Cannulation

Compartment Syndrome

Distal Perfusion Cannula Insertion Options (antegrade)
Open Cannulation Techniques Using Synthetic Graft

Problem with Percutaneous Femoral Cannulation for VA ECMO

- Percutaneous cannula occludes the vessel
- Lower limb hypo-perfusion and ischemia
- May require fasciotomy or amputation
- Associated with ischemic complication 11-52%
- Surgical intervention required in 9-22%
- Amputation occurring in 2-10%

Use of distal perfusion in peripheral extracorporeal membrane oxygenation

Makdisi, Makdisi, Wang

Distal Perfusion Cannula Insertion Options (retrograde)
Lack of distal perfusion cannula
ECMO cannula less than 20 French
Need for dialysis
Ipsilateral cannulation
Young age (trend)

Pressure criterion for placement of distal perfusion catheter to prevent limb ischemia during adult extracorporeal life support

- Measured pressure in SFA 2-3 cm from cannulation site
- 23 gauge needle to transducer
- If pressure was < 60 mmHg, added 8.5 F CVP catheter to SFA
- Flow ranged from 168-350 mL/min
- When flow decreased, checked for thrombus or compartment syndrome

Ultrasound Guided Femoral Cannulation and Percutaneous Perfusion of the Distal Limb for VA ECMO

Filippo Benassi, M.D., Antonella Vezzani, M.D., Luigi Vignali, M.D., and Tiziano Gherli, M.D.
POCUS vs Fluoroscopy vs Landmark guidance

One hundred and twenty eight patients undergoing p-ECMO

Utilization was 54% POCUS, 34% Fluoroscopy & 10% Landmark guidance

Misplacement of cannula occurred 3 cases (landmark only group)

CONCLUSION - POCUS guided cannulation preferred method over Fluoroscopy and Landmark guided techniques

Feasibility of smaller arterial cannulas in venaarterial extracorporeal membrane oxygenation

Herso Takyazmi, MD, PhD,5 Elvis Landes, MD,1 Loren Troby, BS, Kevin Fujita, BS,3 Ayas I, Koteru, MD, SUG,6 Linda Mengen, CCP,5 Melina Yar polyakova, MD,1 Paolo C. Columbus, MD,1 Ulrik F. Jorde, MD,3 Pad. A. Katarzysz, MD,5 Roj E. Askoo, MD, PhD,5 Yoshiki Naka, MD, PhD,5

Utilize 15 F (Group S) vs 17-24 (Group L) f femoral arterial cannula

101 patients 2007-2013 n=50 Group L, n=50 Group S. Endpoints were overall status and cannula-related events

No differences in demographics or severity of illness. Group L had higher flow index @ 24h (2.2 vs 1.7 P<0.001). Group L had higher cannula site bleeding (28% vs 10%, P=0.03). 30 d survival was similar 55% vs 52%. Overall bleeding complications higher in Group L (53% vs 32%

15 F cannula selection appears to provide comparable clinical support with reduced bleeding
Using near-infrared reflectance spectroscopy (NIRS) to assess distal limb perfusion on venoarterial (V-A) extracorporeal membrane oxygenation (ECMO) patients with femoral cannulation

Kilian Facioni-Reyes, James Beck, Kenneth Fung, Christine Chan, Matthew Beck, Hironaka Takeyama, and Koji Takeda

Table 1: Diagnostic capability of SO2 <55% for detecting distal ischemia

<table>
<thead>
<tr>
<th>Sensivity</th>
<th>Specificity</th>
<th>PPV</th>
<th>NPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>100%</td>
<td>90%</td>
<td>100</td>
<td>90%</td>
</tr>
<tr>
<td>H1osp or H2osp</td>
<td>100%</td>
<td>90%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Table 2: Diagnostic capability of SO2 <55% for detecting femoral-related obstruction.

<table>
<thead>
<tr>
<th>SO2 Difference (mmHg)</th>
<th>0</th>
<th>20</th>
<th>40</th>
<th>60</th>
<th>80</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensivity</td>
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<td>60%</td>
<td>40%</td>
<td>20%</td>
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<td>100</td>
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</tr>
<tr>
<td>NPV</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
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</tr>
</tbody>
</table>

Distal Perfusion Cannula Flow Rates

Distal Perfusion Cannula Flow Rates

Prevention of Distal Limb Ischemia During Cardiopulmonary Support via Femoral Cannulation

Kevin L. Greason, MD, James R. Hemp, MD, J. Matthew Maxwell, MD, John E. Fetter, MD, and Ricardo J. Moreno-Lubrano, MD

Department of General Surgery, Cedars-Sinai Medical Center, Los Angeles, California

Table 3: Limitations of distal perfusion cannulaes

<table>
<thead>
<tr>
<th>Limitation</th>
<th>Overall Complication (n = 78)</th>
<th>DPC (n = 65)</th>
<th>NSPC (n = 13)</th>
<th>p Value</th>
</tr>
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<tbody>
<tr>
<td>Limb ischemia</td>
<td>11 (14%)</td>
<td>10 (15%)</td>
<td>1 (8%)</td>
<td>0.01</td>
</tr>
<tr>
<td>Hemorrhage</td>
<td>5 (6%)</td>
<td>4 (6%)</td>
<td>1 (8%)</td>
<td>0.18</td>
</tr>
<tr>
<td>Infection</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>1.00</td>
</tr>
<tr>
<td>Patients with diabetes Mellitus</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>1.00</td>
</tr>
<tr>
<td>Patients with hypertension</td>
<td>7 (9%)</td>
<td>6 (9%)</td>
<td>1 (8%)</td>
<td>0.78</td>
</tr>
</tbody>
</table>

Distal Perfusion Cannulation and Limb Complications in Venoarterial Extracorporeal Membrane Oxygenation

Asthma Elmasry, MD, Thomas Boha, MD, Sandi Kim, MD, Ashwad Afzal, MD, Amsterdam R. de Brou, MD, William J. Dohler, MBA, T. Xavier Gay, MD, Marissa D'Aprix, MD, José Galván, MD, Arash Salteni, MD, Berhane Worku, MD

New York Presbyterian Hospital-Cornell Medicine, New York, New York

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<td>0.78</td>
</tr>
</tbody>
</table>
Is a Distal Perfusion Catheter Necessary for Avoidance of Limb Ischemia?

- Reduces risk of ischemic injury
- Not needed when using a graft on femoral artery
- Aggressive assessment is required
- Avoid ipsilateral cannulation
- Arterial cannula size
Disclosures

I have NO financial disclosures or conflicts of interest with the presented material in this presentation...

…but I would like some!

Oxygenation Determinants and Physiopathology of VV ECMO

\[ S_aO_2 = \frac{S_{pa}O_2 \times (\frac{EF}{CO})}{S_{m}O_2 + (1-\frac{EF}{CO})S_vO_2 + 0.01(P_mO_2) + RLF} \]

- \( S_aO_2 \): Arterial Oxygenation Sat (%)
- \( S_{pa}O_2 \): Pulm Artery Oxygenation Sat (%)
- \( S_{m}O_2 \): Post-Membrane Oxygen Sat (%)
- \( S_vO_2 \): Mixed Venous Sat (%)
- \( P_mO_2 \): Dissolved Oxygen Content (%)
- \( RLF \): Residual Lung Function

EF = Effective Flow = (1 – R)PF
CO = Cardiac Output
P_mO_2 = Pump Flow
R = Recirculation
The VV ECMO Proof

**IF:**
- Native lung function is poor—does not contribute to oxygenation (RLF = 0)
- Partial Pressure of Oxygen is negligible
- Negligible bronchial artery blood flow
- No intracardiac shunts (Qp:Qs Ratio is 1:1)
- Right ventricle receives:
  - Net VV ECMO output flow (EF)
  - Total systemic venous return not captured by VV ECMO Cannula (1 - EF/CO)S\textsubscript{v}O\textsubscript{2}
  - Cardiac venous drainage (Coronary Sinus and Thebesian veins)

**THEN:**
Net VV ECMO output provides the 100% of the oxygen delivered to the body

\[ \text{S\textsubscript{v}O\textsubscript{2}} = (\text{EF/CO})\text{S\textsubscript{m}O\textsubscript{2}} + (1 - \text{EF/CO})\text{S\textsubscript{v}O\textsubscript{2}} \]

Why are the Saturation Low???

- Decrease in Effective Flow (EF) = Increase in Recirculation (R)
- Cannula Malposition?
- Cannula Migration?
- Increase in Cardiac Output (CO)
- Decrease in EF/CO Ratio?
- Decrease in \text{S\textsubscript{m}O\textsubscript{2}}
- Oxygenator efficiency?
- Inadequate blender settings?
- Decrease in Residual Lung Function (RLF)
- Is lung function getting worse?
- Is ventilation strategy optimized?

Hypoxemia During VV ECMO

**Main Mechanisms**
- Blood Flow/Cardiac Output
- Recirculation
- High Pulmonary Shunt
- Oxygenator Dysfunction

Oxygen Supply vs Demand

Persistent Hypoxemia is defined
- \( P_{O_2} < 50 \text{ mmHg} \)
- Arterial Sat of < 85%

However, even with maximizing all strategies and efficiency, hypoxemia may still persist.

Remember it is about the \( O_2 \)
- Lactate?
- Urine output?
- Mental Status?

Avoidance of concomitant hypercapnia
Harlequin Syndrome During VA ECMO

Cory M. Alwardt, PhD, CCP
Chief Perfusionist / ECMO Coordinator
Assistant Professor of Surgery
Mayo Clinic Hospital, Phoenix

What is Harlequin Syndrome?

- A condition that can occur during peripheral VA-ECMO in which the patient’s head will appear blue while the lower extremities will be pink.
- Caused by ECMO blood flow coming up the aorta in a retrograde fashion and mixing with native cardiac output.
- Also referred to as:
  - North-South syndrome
  - Dual circulations
  - Regional hypoxia
  - “Mixing cloud” phenomena

Ghalayini et al, 2016
Alwardt et al, 2013
Upper body hypoxia during VA ECMO

- Wada et al. (2000)\(^3\) induced respiratory failure in dogs and placed them on VA-ECMO using both the right femoral artery and left axillary artery.
- Used near infrared spectroscopy (NIRS) to look at regional oxygenation.
- Used each cannulation site for 15 minutes, then measured blood gases at different locations.

Wada et al., 2000 \(^3\)

Avgerinos et al. 2013 \(^4\)

<table>
<thead>
<tr>
<th>Cannulation</th>
<th>SpO(_2) (Central)</th>
<th>SpO(_2) (Radial)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antegrade Axillary</td>
<td>99%</td>
<td>99%</td>
</tr>
<tr>
<td>Antegrade Central</td>
<td>99%</td>
<td>99%</td>
</tr>
</tbody>
</table>

Harlequin Syndrome

AnaSECTInternational
Avgerinos et al, 2013

<table>
<thead>
<tr>
<th>Cannulation</th>
<th>Radial Artery (SpO₂)</th>
<th>Femoral Artery (SpO₂)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antegrade</td>
<td>99%</td>
<td>99%</td>
</tr>
<tr>
<td>Axillary</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Central</td>
<td>99%</td>
<td>99%</td>
</tr>
<tr>
<td>Retrograde</td>
<td>97%</td>
<td>99%</td>
</tr>
<tr>
<td>Femoral - severe lung injury</td>
<td>73%*</td>
<td>99%</td>
</tr>
<tr>
<td>Retrograde</td>
<td>73%*</td>
<td>99%</td>
</tr>
</tbody>
</table>

Analyzed 20 patients on VA ECMO

Harlequin Syndrome

De Biasi et al, 2015

- Case Report on 74 year old man with fem-fem VA ECMO
- Aortography used to visualize ECMO blood flow, contrast injected near the bifurcation of the aorta
- All images taken with pulse pressure of 9 mmHg
No contrast seen in ascending aorta (G) or coronary arteries (H).

Alwardt et al, 2013

- Case report on 35 year old male
- Underwent heart transplant and HVAD removal
- Presented to ED 17 months post transplant with acute rejection
- Placed on femoral VA ECMO

At 14 hours, blood gases at ECMO arterial line and right radial artery are similar.

<table>
<thead>
<tr>
<th>Blood gas values</th>
<th>Right</th>
<th>ECMO Arterial</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>7.36</td>
<td>7.42</td>
</tr>
<tr>
<td>PaO2 (mmHg)</td>
<td>90</td>
<td>120</td>
</tr>
<tr>
<td>SatO2 (%)</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>HCO3^- (mEq/L)</td>
<td>23</td>
<td>26</td>
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Alwardt et al, 2013

At 24 hours, blood gases at right radial artery do not reflect ECMO blood.

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<tr>
<td>HCO3^- (mEq/L)</td>
<td>23</td>
<td>26</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ECMO settings</th>
<th>Blood flow (L/min)</th>
<th>FO2 (%)</th>
<th>Sweep (L/min)</th>
<th>Ventilator settings</th>
<th>Tidal volume (mL)</th>
<th>Minute ventilation (mL/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5.5</td>
<td>75</td>
<td>3.5</td>
<td>40</td>
<td>10</td>
<td>5840</td>
</tr>
</tbody>
</table>
At 31 hours it’s worse, so...

...a left radial line was inserted

---

**Assessment of Harlequin Syndrome**

- Blood gas analysis – ECMO arterial vs. patient arterial
  - Consider the pulse pressure
  - Always use right radial when possible
- Pulse oximetry (left vs. right hand)
- Regional and cerebral oximetry
Assessment of Harlequin Syndrome

**Why right radial?**

- It's the best approximation of coronary oxygenation
- Can give information regarding oxygenation of the brain
- Gives you a goal!

Management of Harlequin Syndrome

- Maximize ECMO blood flow
- Consider minimizing LV ejection (PP ~ 10 mmHg?)
- Discontinue inotropes
- Diuretics/dialysis
- Vent the heart
- Consider esmolol
- Ventilator management
- May try and oxygenate the blood in the native circulation
- May help minimize coronary ischemia
- Hybrid ECMO

What is Hybrid ECMO?

- Hybrid between VA and VV ECMO
- Essentially it's VA ECMO, but with the addition of oxygen to the right heart
- Blood ejected from the LV now has more oxygen

Management of Harlequin Syndrome

- Optimize venous cannula position?
- Take advantage of “mixed venous” blood
Venous cannula positioning

- In the scenario shown here, you are allowing blood with a lower saturation to (mostly) flow through the heart.
- If you move the cannula into the SVC, you drain blood with a lower saturation and allow the higher saturation to flow through the heart.

Other key points

- Harlequin Syndrome does not happen with VV ECMO because all mixing occurs prior to the systemic circulation
- Harlequin Syndrome does not happen, at least classically, with central VA ECMO cannulation, but…

Coronary oxygenation with central VA ECMO

- Coronary blood flow (in newborn lambs) was predominately derived from the LV, despite the ECMO cannula being 2 to 3.5 cm from the aortic valve (Kinsella et al, 1992)

Coronary oxygenation with central VA ECMO

- In a dog model with an arterial ECMO cannula in the common carotid artery, the ECMO blood did not pass in a retrograde fashion to the aortic root (Kato et al, 1996)
Coronary oxygenation with VA ECMO

- Just because you don’t have a classic Harlequin Syndrome doesn’t mean that you are adequately oxygenating the coronary arteries.
- This is true for both peripheral and central cannulation.

Take home points!

- A thorough understanding of Harlequin Syndrome is imperative to managing patients on VA ECMO
- Blood gases and pulse pressure usually tell the story
- You should understand maneuvers to manage Harlequin Syndrome when necessary (flow dynamics, vent management, etc)
- Coronary oxygenation during VA ECMO may be problematic with both peripheral and central cannulation with lung failure.

References:

Disclosures
- Research Associate Professor SUNY Upstate Medical University
- Science Officer Biomedical Simulation Inc.
- Consulting professor XtraCorp Inc
- No financial disclosures relative to this presentation

Presentation Outline: Goals
- List the basic elements of an ECMO hemostasis strategy
- Report where the current literature is leading us
- Outline current adult ECMO anticoagulation control and monitoring strategies
Risks

FDA Executive Summary

Prepared for the September 12, 2013 meeting of the Circulatory System Devices Panel

Classification of the Membrane Lung for Long-term Pulmonary Support [Extracorporeal Membrane Oxygenator – ECMO (21 CFR 888.5610)]

ECMO Anticoagulation Strategies

Ideally, platelet function and hemostasis activation should be inhibited to minimize clot formation within the ECLS circuit and patient while maintaining endogenous procoagulant activity to prevent hemorrhagic complications.

Recent ELSO Guidelines

Elements to Consider: ECMO Hemostasis Strategy

Pre-ECMO
1. Assess the patient for hemostasis and anticoagulation
2. Cannulation: Protect the patient from thrombosis

On-ECMO
1. Protect / monitor patient for bleeding, HITTS, DIC; And the ECC for thrombosis
2. Monitor patient for anticoagulation, low AT levels, thrombocytopenia, hypercoagulability, hemolysis, and fibrinolysis
3. Monitor patient transfusion requirement, and minimize blood sample frequency and sample waste volume

Post-ECMO
1. Continue to monitor patient for thrombosis and hypercoagulability

Pediatr Crit Care Med 2013: Survey

- Setting: Extracorporeal Life Support Organization-registered ECMO centers internationally
- Design: Internet-based, cross-sectional survey
- Patients: None
- Method: Survey to May 2011
- Results: 121 responses from 187 ELSO centers; 84% have protocols; 69% use partially heparin-bonded ECCs; Serial measurement of ACT is preferred monitoring method
- Learning: 43% reported use of TEG; 21% use TEG routinely
- Level of Recommendation – Evidence: IIb-C
**Cell-Based Coagulation Model**

![Cell-Based Coagulation Model Diagram]

**Adult ECMO Anticoagulation Strategies**

### ECMO Anticoagulation Literature

**Adult ECMO Anticoagulation Literature**

- **Authors:** Esper SA, Levy JH, Waters JH, Welsby IJ.
- **Title:** Extracorporeal Membrane Oxygenation in the Adult: A review of anticoagulation monitoring and transfusion
- **Journal:** Anesth Analg
- **Volume:** 2014
- **Pages:** 731-43.

**Adult ECMO Anticoagulation Strategies**

**Veno-Venous ECMO / Veno-Arterial Resuscitation Closed Chest**

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<tr>
<td>Heparinase TEG or ROTEM</td>
<td>Monitor patient for fibrinolysis</td>
<td>Avoid anticoagulation</td>
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**Veno-Arterial ECMO: Post-Cardiotomy**

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Summary

- Study the numerous review articles and [retrospective] cohort studies comparing ECMO anticoagulation strategies
- Future watch
  - Infusion of short acting antiplatelet drugs [Cangrelor and GPIIb/IIIa Inhibitors]
  - Better blood handling surfaces, and
  - An antidote for DTIs [FIIa, and others?]
- Study your own internal patient data
- Do your own evidence-based tests of change (QIP)

rileyjb@gmail.com